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Supporting Information

High Performance MoO_{3-x}/Si Heterojunction Photodetectors with Nanoporous Pyramid Si Arrays for Visible Light Communication Application

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1. Calculation method

Calculations of the depletion layer thickness (*W*) and the hole drift time (τ_p) in depletion layer.

The depletion layer thickness (*W*) can be calculated by:

$$W = \sqrt{\frac{2\varepsilon_s V_{bi}}{qN_D}} \quad (1)$$

ε_s is dielectric constant of silicon (11.9[1]), V_{bi} is the build-in potential (~670 mV), q is the unit electron charge and N_D is the doping concentration (2×10^{15} cm^{-3}). The depletion layer thickness was calculated as 223 nm.

The hole drift velocity is defined by:

$$V_P = \mu_P E \quad (2)$$

The μ_P is the hole mobility in silicon (450 cm^{2}V^{-1}s^{-1} in silicon with doping concentration of 2×10^{15} cm^{-3}) and E is built-in electric field and can be calculated by:

$$E = \frac{V_{bi}}{W} \quad (3)$$

According equation (1) (2) (3), the hole drift velocity (V_P) was calculated to be 1.5×10^5 m s^{-1}.

Therefore, the hole drift time (τ_p) was calculated by:

$$\tau_p = \frac{W}{V_P} \quad (4)$$

And the hole drifting time (τ_p) was estimated to be 2.23 ps.

Estimation of rise time (τ_r)

The diffusion length (L) of minority carrier and minority carrier lifetime (τ) is associated with the following formula:

$$L = (D \cdot \tau)^{1/2} \quad (5)$$

D is diffusion coefficient, and it is defined by:

$$D=\mu_P \cdot \frac{kT}{q} \qquad (6)$$

The μ_P is the hole mobility in silicon. k is Boltzmann constant. T is *Kelvin* temperature (300 K at room temperature). q is the unit electron charge.

According to (5) and (6), the minority carrier diffusion velocity (V) is calculated by

$$V=\frac{L}{\tau}=\frac{\sqrt{D\tau}}{\tau} \qquad (7)$$

The lifetime (τ) can be found in the related article [2]. The lifetime in n-type silicon (doping concentration of 2×10^{15} cm^{-3}) is about 20 μs.

Therefore, the rise time τ_r was calculated by the equation:

$$\tau_r=\frac{l}{V} \qquad (8)$$

l is the thickness of silicon wafer (450 μm). According to above formula, the rise time was estimated to be 73 μs.

2. Table S1

The overall photodetecting performance of three devices.

Heterojunction structure	***R (mA/W)***	***τ_r (μs)***	***τ_d (μs)***	***f_{-3dB} (Hz)***	***D* (jones)***	***SNR***
Planar	54	5.4	130	2.1×10^3	4.99×10^{12}	2.5×10^4
Pyramid	79	1.89	58	1.0×10^4	7.3×10^{12}	8.5×10^4
NPPAs	138	0.87	23	5.0×10^4	1.27×10^{13}	1.51×10^5

3. Figures

Figure S1

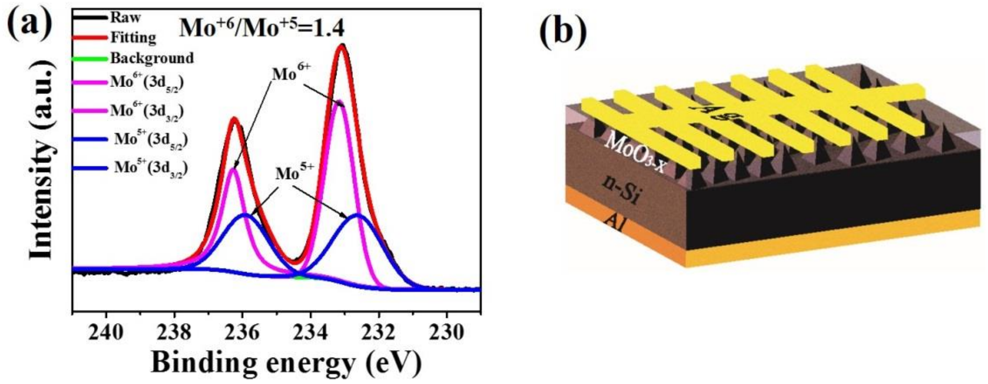

Figure S1. (a). XPS spectrum of as-deposited MoO_{3-x} thin films. (b). Schematic diagram of the MoO_{3-x}/ n-Si heterojunction photodetector with pyramid structure.

Figure S2

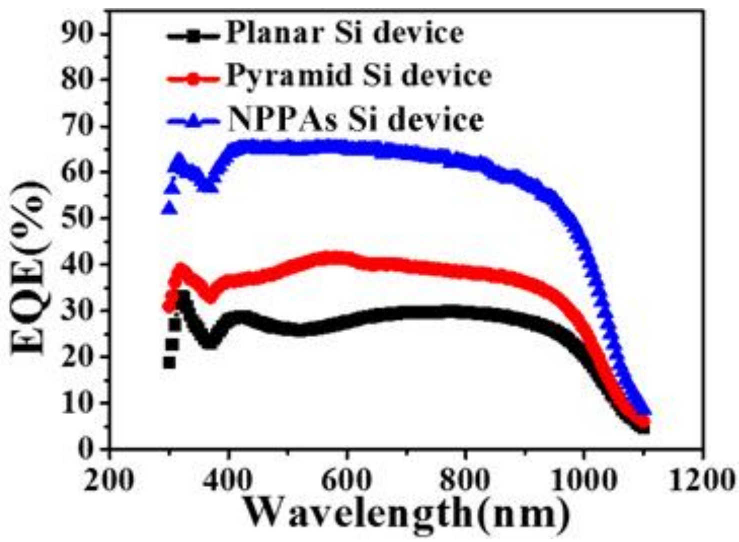

Figure S2. External quantum efficiency (EQE) of three devices ranges.

Figure S3

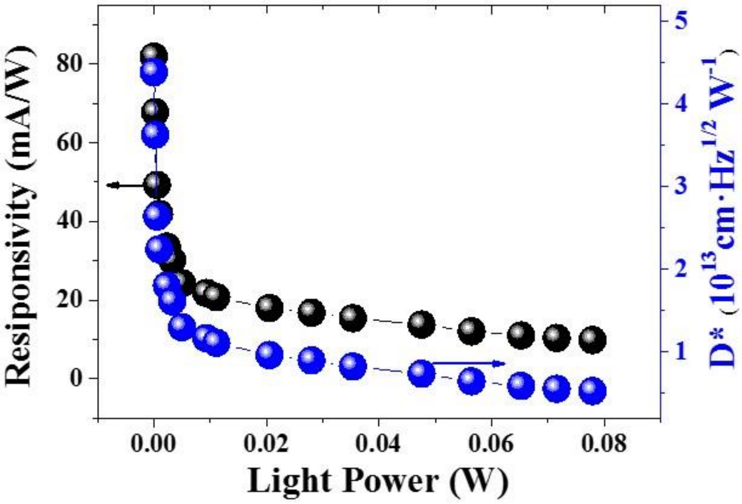

Figure S3. The detectivity (D^*) and responsivity (R) of NPPAs device under different power density of 650 nm laser.

Figure S4

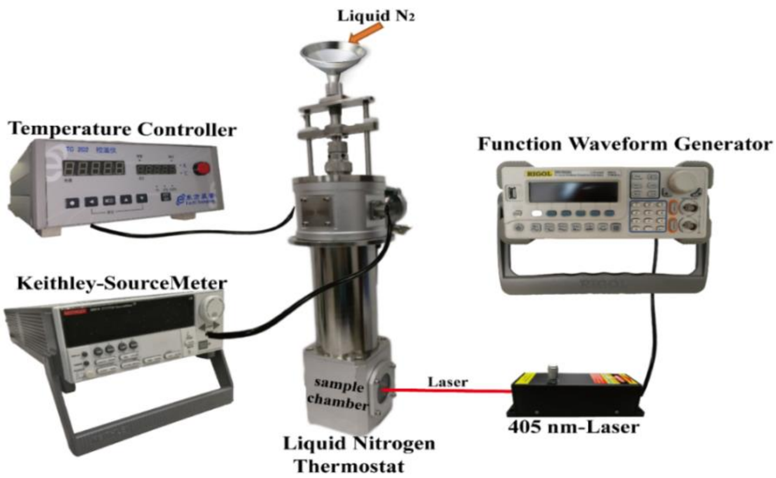

Figure S4. The setups for temperature cycling measurements.

Figure S5

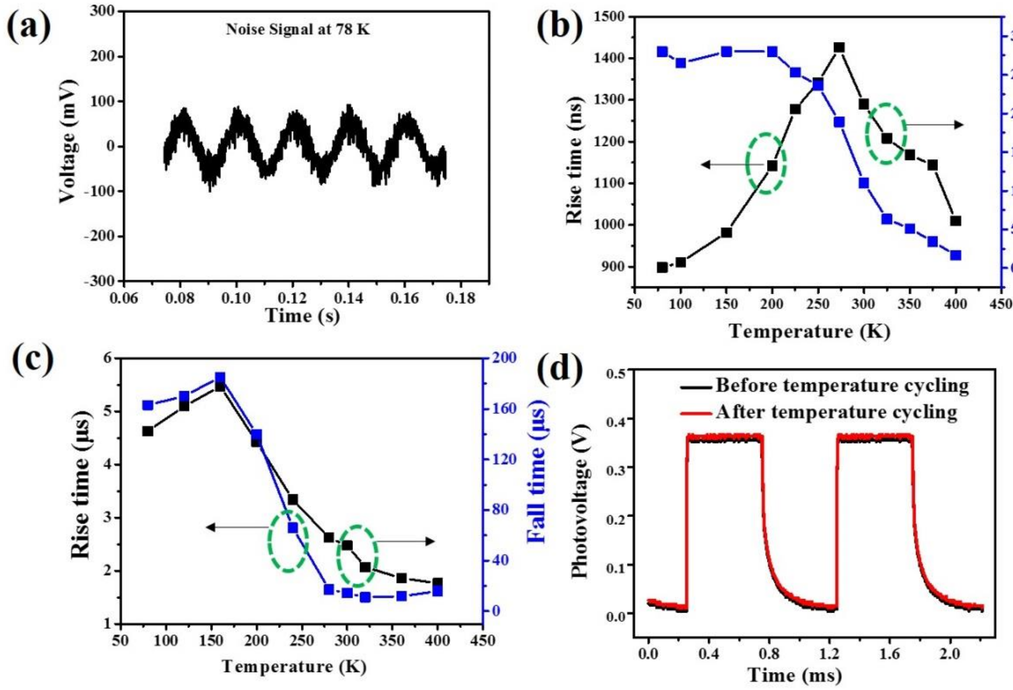

Figure S5. (a). The background noise signal at 78 K. (b, c). The photoresponse time of planar device and pyramid device under various temperature (650 nm, 118 mW/cm^2, 100 Hz). (d). The photoresponse curves of NPPAs photodetector before and after temperature cycling.

Figure S6

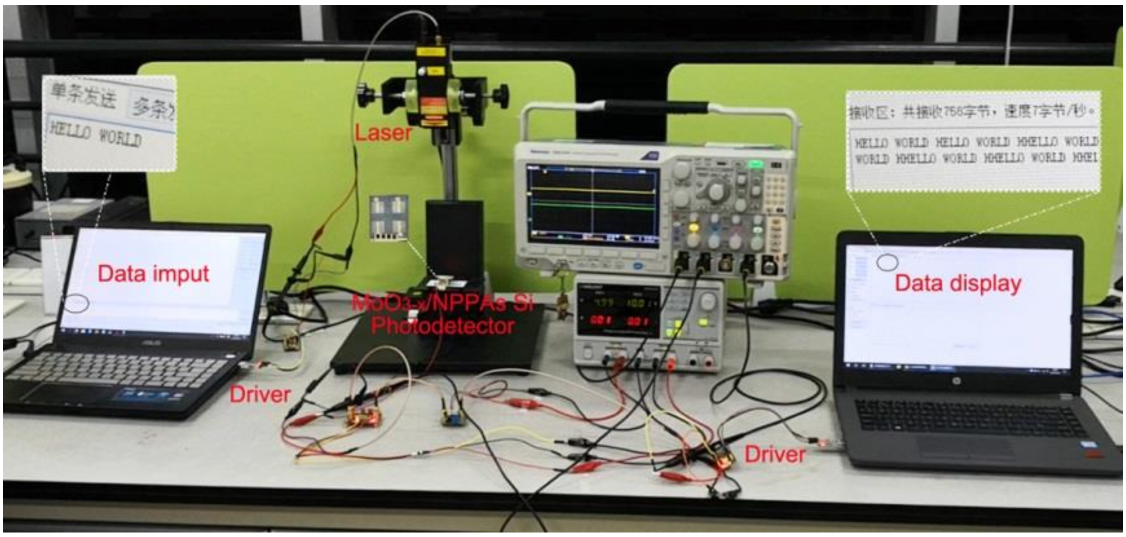

Figure S6. Digital photograph of the visible light communication (VLC) system with our MoO_{3-x}/Si heterojunction photodetector as light signal receiver. The red arrows indicate the data flow direction.

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1. Mojtaba, D.; David, C. J., Graphene Microstrip Patch Ultrawide Band Antennas for THz Communications. *Adv Funct Mater* **2018,** *28* (11), 1705925.

2. Panek, P., The Influence of the Base Material Parameters on Quantum and Photoconversion Efficiency of the Si Solar Cells. *Archives of Metallurgy and Materials* **2016,** *61* (4).